UNITED STATES COAST GUARD

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NAVIGATION AND VESSEL INSPECTION CIRCULAR 6-72 CHANGE 1 INCLUDED

Subj: Guide to Fixed Fire-Fighting Equipment Aboard Merchant Vessels

1. Purpose. The purpose of the attached guide is to explain the basic characteristics of fixed fire-fighting equipment installed aboard merchant vessels. This is accomplished by discussing how the various fire extinguishing agents function, and by enumerating the important element which must be considered when designing a system. By explaining the principles of system operation it is hoped that design and review of installations will be simplified.

2. Cancellation. This circular and the enclosed guide supersedes the information previously issued as NVIC:14-65.

3. Objectives. The guide is intended to disseminate to Coast Guard technical units, Coast Guard marine inspectors, equipment manufacturers, vessel owners, and shipyards a supplement to and clarification of regulation governing installation of fixed fire-fighting equipment aboard merchant vessels. It is intended to be explanatory only; nothing herein shall be taken as amending the applicable regulations, nor as prescribing nor limit mg the authority or responsibility of the Officer in Charge, Marine Inspection in the exercise of his good judgment.

4. Revisions. It is expected that these notes will require modification in light of their use in the field. Comments and suggestions are welcome, and revisions will be issued as necessary.

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End: (1) Guide to Fixed Fire-Fighting Equipment Aboard Merchant Vessels

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GUIDE TO FIXED FIRE-FIGHTING EQUIPMENT

ABOARD MERCHANT VESSELS

i. INTRODUCTION

The purpose of this guide is to enlarge upon the standard. for the design, installation, and testing of fixed fire extinguishing equipment aboard U.S. flag merchant vessels. It is not intended to modify or in any way change the applicable regulations, rather to supplement and clarify them. The discussion of the various systems is intended to be explanatory only and not meant to indicate preference for a system or systems to be installed on a given vessel. Specific regulations should be consulted to determine protection required in each vessel environment, especially with respect to hazardous or dangerous cargoes.

Fire extinguishing systems should be reliable and capable of being placed into service in simple, logical steps. The more sophisticated the system is, the more essential that the equipment be properly designed and installed. It is not possible to anticipate all demands which might be placed upon fire extinguishing systems in event of emergency. However, potential casualties and uses should be considered, especially as related to the isolation of equipment, controls, and required power from possible disruption by a casualty. Fire protection systems should, in most cases, serve no function other than fire fighting. Improper design or installation can lead to a false sense of security, and can be as dangerous as no installation.

Fixed extinguishing equipment is not a substitute for required structural fire protection. These two aspects have distinct primary functions in U.S. practice. Structural fire protection protects passengers, crew, and essential equipment from the effects of fire long enough to permit escape to a safe location. Fire fighting equipment, on the other hand, is for protection of the vessel. Requirements for structural fire protection vary with the class of vessel and are the most detailed for passenger vessels. However, approved fixed extinguishing systems are generally independent of the vessel's class.

Automated vessels require additional consideration of required extinguishing equipment where a reduced manning scale presents a reduction in number of available fire fighting personnel. Control of all systems or functions relating to fire protection of the machinery space should be centralized in a single accessible location outside the machinery casing. This station should be able to control the fixed fire extinguishing system, the machinery space ventilation, fuel pumps and fuel tank valves subject to a fuel head pressure, the remote fire pump, and the bilge system. (NVC 1-69, H.l.b)

Where fire-extinguishing systems are not required, but are installed, the system shall be in accordance with the applicable regulations.

This guide is divided into six parts, corresponding to the major types of carbon dioxide fixed fire extinguishing systems: (I) firemain, (II) (III) mechanical foam, (IV) water spray, (V) manual sprinkling, and (VI) bromotrifluoromethane. Each portion contains, (a) a discussion of the basic concepts of the system and explanation of the regulations, (b) a check-list guide for use in system design and review, and (c) notes on initial and subsequent tests and inspection of the installation. The part describing each system is contained as a separate portion of the guide, so that the guide may be used as a single booklet form or so that individual portions may be detached and used separately.

I. FIRE MAIN SYSTEM

A. DISCUSSION

A.1. GENERAL

The fire main system is the backbone of all fire-fighting systems on a ship. Water has the greatest heat absorbing capacity of any extinguishing medium in use. It is versatile; it can be used as a straight stream for combating deep-seated fires; it can be applied as a spray for combating combustible liquid fires where cooling and minimum agitation is desired; it can be used as a back-up for protection of personnel where cooling is the primary effect desired. As it absorbs the heat of a fire it may be vaporized to steam, which tends to smother the fire in enclosed spaces. Aboard ship, the quantity of water available for fire fighting is limited only by the capacity of the fire pumps. The disadvantages of water for combating fires aboard vessels are: (1) excessive quantities may impair the vessel's stability, and (2) it should not usually be used on live electrical equipment.

Any fire main installation must be capable of delivering and adequate supply of water to any portion of the vessel quickly for the purpose of combating fires.

The requirements for fire main apply irrespective of other fire protection equipment which may be required. In the case of special design vessels, as nuclear ships, exceptions to this requirement may be granted when it is shown that in certain locations the fire main would act as a detriment. Such proposals must specially be considered during design and plan approval stage.

The regulations specify fire pump capacity, pipe sizes, hydrant locations, hose lengths, etc., usually based upon a performance specification of the final installation. This makes design and review of the system to assure compliance with the regulations more difficult, but no less necessary. Adequate effort at the design, stage is absolutely essential. This is the period in which the size of the pumps, size of the piping, runs of piping, number of fittings, etc. are determined. Once the installation is made, changes to comply with the regulations are almost impossible to effect. Sole reliance should not be placed upon operational tests to determine compliance with the regulations.

A.2. FIRL PUMIPS

A.2.l Fire Pump Location

Most vessels are required to have two fire pumps with all suctions, sources of power, etc. located in separate spaces so that one casualty will not put all pumps out of operation. The alternative of installing both pumps in the same space and protecting the space with carbon dioxide is a deviation , permitted only in unusual circumstances where the separation of pumps will not increase safety - usually accepted for small vessels only. Such an arrangement is a poor substitute for separation of the pumps.

One important objection is that pumps are not required to be controlled from outside of the space. If a fire occurs in the space containing the pumps, the space will become untenable. Even upon discharge of CO_2 and extinguishment of the fire, the spaces will remain untenable, delaying the availability of the pumps. There is a strong probability that when the pumps do become available, they will be inoperable.

As a basis for application of the requirement to separate fire pumps, a fire in one space is considered to be of such magnitude that the entire space, including the machinery space casing, is inaccessible and all equipment therein is made inoperable.

When a pump powered by the emergency electrical system is to be used as one of the independent fire pumps, compliance with this requirement can be deceptive. Complete independence of fire pumps may be lost due to interdependence between electrical Systems and boilers, because runs of electric cable may be vulnerable to fire in several spaces, and because of non fire-proof boundaries of machinery spaces. Some examples of aspects which must be considered are:

(1) A steam fire pump in the boiler room in combination with an electric fire pump in the engine room supplied from the emergency electrical system may not comply with the regulation. If the boilers are dependent on electrically driven auxiliaries, a fire in the engine room may affect not only the electric fire pump, but also the normal electric supply to the boiler auxiliaries required for operation of the steam fire pump.

(2) An electric fire pump located remotely from the main machinery spaces and supplied from the emergency electrical system in combination with another fire pump in a main machinery space may not comply with the requirement. If the cable supplying the remote pump passes through either the boiler or engineroom a fire in that space will affect the machinery space fire pump and may damage the power supply cable to the remote fire pump.

(3) An electric fire pump located outside the main machinery spaces and supplied from the emergency electrical system by a cable and motor starter attached to a machinery space boundary or casing may not be independent of the machinery space. In this situation it is possible for heat from a fire in the machinery space -to be conducted through the boundary or casing and damage the power supply to the fire pump.

(4) An electric pump is located outside of the main machinery spaces and is supplied from the emergency electrical system, the power for which is an independent diesel-drive generator. Location of the fuel supply to the independent diesel-driven generator in the machinery space or casing may nullify the fire pump separation. A machinery space fire could disrupt fuel to the driver for emergency electrical power, thereby putting both fire pumps out of operation.

One additional aspect which must be considered in the arrangement of fire pumps to comply with this requirement concerns "separation" of the spaces. For the purpose of determining compliance with this requirement, the following condition must be met in order for the spaces to be considered "separate."

> (1) Any common boundaries between the spaces must be an effective "A" Class fire division.
>
> (2) To insure that a fire in one pump space does not spread rapidly to an adjacent pump space, doors in common boundaries between the spaces shall be either:

(a) Remotely operated Class II watertight doors, or

(b) Remote release, self-closing fire doors (installed alone or in tandem with dogged watertight doors)

However, doors on the same level as and in close proximity to continuously manned control stations need not be of the self-closing type.

(3) The spaces shall have independent access.

In the advent that there is only a single engine space, it becomes increasingly difficult to find a suitable location for the second fire pump. There are three acceptable solutions to this problem of which the latter is acceptable only in very unusual circumstances. Listed in general order of preference, they are:

(1) <u>Deep well pump</u> - Installation of a deep well pump located in the accommodation and service space area above the machinery space would be acceptable. The suction shaft would pass down through the machinery apace where it would take suction from a sea chest. All electrical components and valving would be located inside of the pump room, providing complete independence from the machinery space. Such an arrangement allows simple rapid operation of the system. Some of the problems which must be considered in such a design are:

(a) Provision of a flexible connection between the pump suction shaft and the pump to avoid undue stresses both at the connection and at the sea chest.

(b) Strength of the sea chest or suction shaft support.

(c) Provisions of fire insulation if the pump space immediately adjoins the machinery space.

(2) <u>Forward pump</u> - If a bow thruster is provided, the fire pump may be located in the forward portion of the ship with power provided by the bow thruster prime mover. Such an arrangement would possibly involve a considerable time delay before the pump could be actuated and remote control of the pump and valves from the accommodation area would be necessary.

(3) <u>A separate enclosure</u> - Building a small separate enclosure inside the machinery space with access from outside the machinery space has several drawbacks.

(a) To assure that a fire in the engine space will not affect operation of the second fire pump, water supply, source of power, power cables, etc. should be independent of the machinery space.

(b) Despite all precautions the space may tend to become a "forgotten space," lacking maintenance, collecting debris, etc.

(c) Access to the space is difficult at best and could be a potential safety hazard due the long distance which must be transversed by a vertical ladder.

(d) There would likely be a considerable time delay before the pump could be started in the advent of a fire in the machinery space.

A.2.2 Fire Pump Capacity

The size of the required fire pumps depends upon the vessel's size and service. It also depends upon the arrangement of the particular fire pump and piping aboard the vessel. In general, pumps are required to be sized as follows:

(I) For passenger vessels, the combined fire pump capacity must be equal to 213 of the required bilge pump capacity. For cargo and tank vassals the capacity of a single fire pump must be at least 2/3 of the capacity of a single required bilge pump, while delivering water through the fire main at the nozzle pitot pressure.

(2) The capacity of an individual fire pump shall not be less than 80% of the total required combined capacity divided by the required number of pumps.

(3) Each individual pump must be capable of supplying the two (three for tankers over 650 feet) hose streams incurring the greatest pressure loss[1] at 50 psi pitot tube pressure (7S psi Pitot pressure for tankers).

When 2 1/2" hydrants are required, the hose discharge as stated in (3) above is assumed to be from 2 1/2" hydrants. If two-l 1/2"[2] hydrants are installed in lieu of one-2 1/2" as permitted by regulation it is assumed that both 1 1/2" hydrants are used. In cases where both 1 1/2" and 2 1/2" hydrants are installed aboard a single vessel, the system should be designed to meet the following conditions:

(1) Combination of required number hydrants (1 1/2" and 2 1/2") incurring the greatest pressure drop, when flowing simultaneously, between the fire pump and the nozzle, and

(2) Combination of required number of 2 1/2" hydrants incurring greatest pressure drop, when flowing simultaneously, between the fire pump and the nozzle.

[1] Passenger & Largo Regulations say two highest, this can be interpreted to mean "incurring greatest pressure loss" if length of the vessel becomes significant (in which case the "friction-head" loss in long piping runs would exceed the "elevation-head" loss of high hydrants).

[2] The combined discharge from two-I 1/2" hydrants is roughly equivalent to that from one-2 1/2" hydrant. (see Paragraph A.7.l Nozzle Discharge).

The stipulation "while flowing simultaneously" is necessary since a combination of the nozzles incurring the greatest pressure drop while flowing individually may not represent the most severe design condition. This can be seen in the following diagram.

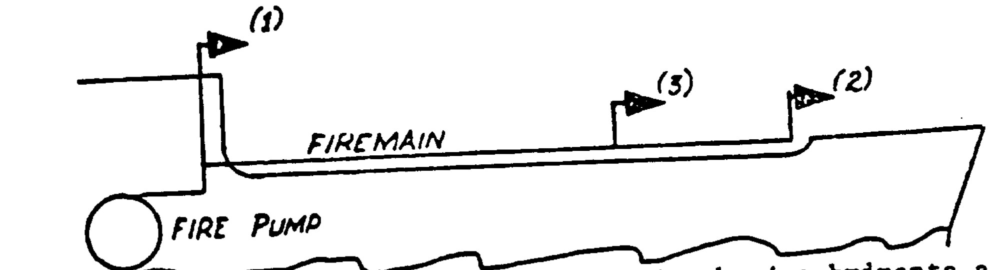

Fig. I.A.1 - Diagrammatic Arrangement of Firemain showing hydrants at which greatest pressure drop may occur.

Assume nozzle (1) incurs the greatest pressure drop alone and (2) incurs the second greatest individual pressure drop. However, the simultaneous flow of nozzles (2) and (3) could produce & combined pressure drop greater than that incurred by the combination of nozzles (1) and (2). If pumps are used for other fire fighting purposes see subsequent discussion in section 5.2. Pump characteristic (capacity vs. head) curves should be provided and examined for all fire pumps. This is the only method by which the adequacy of the pumps may be determined during the design stage. When two pumps are required, their approximate combined capacity should be examined.

2.2.1. Fire Pump Capacity - Example I

Determining the required capacity of fire pumps is perhaps best illustrated by examples. Assume a passenger vessel is required to have the following:

(1) Minimum number of pumps = 2

(2) Required bilge pumping capacity = 1000 gpm

(3) Minimum Pitot tube pressure at two outlets flowing simultaneously = 50 psi

Apply the design conditions noted in paragraph A.2.2:

(1) The combined capacity of fire pumps for passenger vessels must equal 2/3 of the bilge pumping capacity, or in this case:

1000 x 2/3 = 667 gpm, required combined capacity at adequate pressure to produce 50 psi Pitot pressure at nozzle.

(2) Each pump must be capable of supplying 2 hose streams at 50 psi Pitot pressure, which means each pump must produce:
2 x 160 gpm[3] = 320 gpm, at adequate pressure to produce 50 psi Pitot pressure at nozzles.

[3] 160 gpm is flow through one 7/8" diameter nozzle, see derivations in Section 7

Since a minimum of two fire pumps is required, the minimum combined capacity based on (2) above is:

2 x 320 gpm = 640 gpm

So in this case, criteria (1) determines the minimum required combined capacity (667 gpm).

The minimum capacity of any one pump, as determined by (2) above is 320 gpm. However, there is another criteria for the minimum capacity of a single pump which must be tested; this criteria is listed in paragraph A.2.2(2). Applying this criteria, the minimum capacity of a single fire pump would be:

$\frac{667\,gpm}{2} \times 80\% = 266.4$[4] gpm (note: This is less than the minimum of 320 gpm required for 50 psi Pitot pressure).

We now have calculated the minimum combined capacity (667 gpm) and the minimum individual capacity (320 gpm) of all fire pumps. It now remains only to select the number and capacity of pumps to be installed. If the minimum of two fire pumps is installed, the each pump should be at least equal to:

$$\frac{667\,gpm}{2\,pumps} = 333\,gpm\,/\,pump$$

However, if three pumps are installed when only two are required the capacity of each pump based on the necessary combined capacity is:

$$\frac{667\,gpm}{3\,pumps} = 222\,gpm\,/\,pump$$

This is less than the required minimum of 320 gpm per pump deter-mined previously. So if -three pumps are installed to meet the 667 gpm combined requirement, they must each produce 320 gpm, or the three pumps would have a minimum combined capacity of:

$$3\,pumps \times 320\frac{gpm}{pump} = 960\,gpm$$

A second example: *****

Assume a cargo vessel is required to have the following:

(a) Minimum number of pumps = 2

(b) Required bilge pump = 600 gpm

[4] Divided by required number of pumps

(c) Mininu.m Pitot tube pressure at two outlets flowing simultaneously = 50 psi.

Apply the design conditions noted in paragraph A.2.2:

(1) The capacity of a single fire pump must be at least 2/3 of the capacity of a single required bilge pump, or in this case:

600 x 2/3 = 400 gpm, required capacity at adequate pressure to produce 50 psi Pitot pressure at nozzle.

(2) Each pump must be capable of supplying two hose streams at 50 psi Pitot pressure, which means each pump must produce:

2 x 160gpm = 320 gpm, at adequate pressure to produce 50 psi Pitot pressure at nozzles.

Therefore, in this example 2/3 of the single bilge pump capacity is the governing criteria.

A.2.3. Availability of Fire Fighting Water

The General Assembly of the Inter-governmental Maritime Consultative organization agreed on a number of fire safety improvements to be required of passenger vessels operating on an international voyage. These improvements were put into force for U.S. vessels by amendments to Subchapter II - Passenger Vessels, Chapter I, Title 46 CFR. Among the amendments is addition of a new section 76.10-3, which requires ready availability of fire fighting water for passenger ship on an international voyage. A number of questions have arisen regarding interpretation of this section. The objective of the section is to insure that fire fighting water is available in the shortest possible time, either by maintaining water pressure in the fire main or by installing convenient remote controls for fire pump operation. Specific acceptable means for providing water availability are:

(1) Maintenance of Water Pressure - Water pressure may be maintained in the fire main at all times that passengers are on board. The pressure may be maintained by one of the required fire pumps. This would provide an immediately available quantity of water adequate for initial fire fighting efforts. Alternatively, another suitable pump such as a salt water service pump may be used to maintain the pressure. This pump should have a capacity of at least 75 gpm at 50 psi pressure. If such a pump is used, an alarm shall be fitted in the engine service pump may be used to maintain the pressure. This pump should have a capacity of at least 75 gpm at 50 psi pressure. If such a pump is used, an alarm shall be fitted in the engineroom which will sound upon a pressure drop in the system. This arrangement would provide a limited quantity of water for immediate use, with the assurance that more water will be available within a reasonably short period.

(2) Remote Control of Fire Pumps - If ships were not originally designed for maintenance of pressure on the firemain, it may be practicable to convert them to such service. When pressure is not maintained, at least two of the required fire pumps shall be capable of remote operation. The fire pumps capable of remote operation shall be effectively separated so that a single fire will not put both pumps out of operation. Thus, in any emergency at least one fire pump can be rapidly placed into service from a normally manned or readily accessible location. Remote operation shall consist of the following:

(a) If located in a normally manned machinery space, the fire pump and all valves requiring operation for effective delivery of water to the fire main shall be capable of operation from the manned operating platform within that machinery space. This will permit water to be delivered to the firemain very shortly following sounding of the fire alarm or special crew alarm. Valves required to be remotely operable include not only the inlet valve to the fire main but also valves to other systems supplied by the fire pump. Control of these valves is necessary to insure that fire fighting water is not inadvertently misdirected.

(b) If located in a normally unmanned machinery space, the fire pump and associate valves shall be capable of control from outside that machinery space. Spaces considered suitable for location of the controls include:

(i) The fire control station, if any;

(ii) The bridge, if there is no fire control station; or

(iii) A readily accessible position outside of the machinery space, near the ventilation shut-down, the remote fuel oil stops, and the release for the installed fire extinguishing system.

Control locations shall be clearly and conspicuously marked. Control of fire pumps located in unmanned spaces in the fore-going manner is intended to provide ready availability of fire fighting water in event of a fire in the normally manned machinery space.

The foregoing are intended as illustrations of acceptable means for providing ready availability of fire fighting water. Other arrangements may be accepted, on an individual basis, providing availability of water is equivalent to that specified in the preceding paragraphs

Means of providing the ready availability of water specified for U.S. ships may also be used as a guide in interpreting Regulation 86(b) of Enclosure (1) to NVIC 2-68, for foreign flag passenger ships.

A.3 PIPE SIZING

One requirement for pipe sizing is a performance criterion. Firemain systems must be so designed and the piping so sized that when performance-tested the piping will deliver a quantity of water sufficient to meet the minimum nozzle pressure requirements previously discussed. Briefly, again, these are:

(1) Deliver water at minimum required Pitot tube pressure to the required number of nozzles flowing simultaneously.

(2) Simultaneously supply other systems which are connected directly to firemain.

The National Fire Protection Association Handbook[5] has numerous friction loss tables for piping which may be used in approximating pressure losses in the firemain. Other tables may be equally acceptable if the source of the data is identified.

The firemain must be capable of delivering the quantity of water produced by two fire pumps operating simultaneously. This quantity of water must be delivered to a number of adjacent hydrants at a minimum Pitot tube pressure of 50 psi. For example, assume a single fire pump is required to supply 2-2 1/2" hydrants at 50 psi Pitot pressure. By referring to A.7, we know this is the same as saying the pump must produce 320 gpm at 50 psi Pitot pressure. Then the firemain must be of sufficient diameter to deliver $\frac{320 gpm}{pump} \times 2(pumps)$ = 640 gpm from a number of adjacent hydrants. The number of hydrants will usually be twice the number required to be supplied by a single pump, or in this example: $\frac{2 hydrants}{pump} \times 2 pumps = 4 hydrants$.

A.4. VALVES

The tank vessel regulations require a sufficient number of Valves to isolate damaged sections of piping. This requirement, read in conjunction with the statement that "operation of the foam system shall not interfere with simultaneous use of the fire main", should be taken to require block valves in the deck fire main at least at intervals which accommodate or correspond to the spacing of block valves in the deck foam main. All parts of the fire Rain located on exposed decks shall either be protected against freezing or be fitted with cut-out valves and drain valves so that the entire exposed parts of such piping may be shut off and drained in freezing weather. Except when closed to prevent freezing, such valves shall be sealed open.

Fire Rain root shut off valves not required in the fire main at each deck level. However, installation of such valves for isolation of individual decks may be of positive value at some locations.

A.5. USE OF FIRE PUMPS FOR OTHER PURPOSES

Fire pumps Ray be used for purposes other than supplying water to the fire main provided one of the required pumps is kept available for use on the fire Rain at all times. "Available

[5] Superscripts refer to references.

for USC" means that any or all of the required pumps Ray be used for non-vital services. With control valves for other services at a manifold adjacent to the pump, in event of fire any other service may be readily secured as the valve to the fire Rain is opened. Availability does not mean that the pump must be reserved exclusively for the fire main. Reliability of fire pumps is probably improved if they are used for other services, ensuring proper pump maintenance.

A.5.l. Other than Fire-Fighting

The fire main is a tempting source of "free" water; it is already installed in most spaces. However, injudicious use quickly reduces the reliability of the system. Connections to the fire main for purposes other than fire-fighting, deck wash (and tank cleaning on tankers) should be only from a discharge manifold near the pump unless specific exceptions are granted.

Connections to the fire main for low water-demand services in the forward portion of the vessel (such as anchor wash, forepeak educator, or chain locker educator) have frequently been permitted. In such cases, each fire pump must be capable of meeting the hose stream requirements with the other-service connection open. This prevents the inadvertent opening of the other-service connection from destroying the effectiveness of the fire main system.

The specific purposes for which use of the fire Rain is permitted by regulation, i.e. deck wash and tank cleaning, have one important factor in common: Someone knows that the system is in use and is usually in attendance. Such usage should not be left unattended.

A.5.2. Fire Fighting

Connections to the fire main for other fire-fighting purposes are permitted. Sizing the fire pumps depends on what other system is installed and where it connects to the fire main system. If fire pumps are used for other fire-fighting systems, they must be sized as follows:

A.5.2.1. Foam System

(1) When the foam system is connected at the fire pump manifold, one fire pump may supply the foam main and one pump the fire main.

(2) When the foam system is connected to the fire main at other than the fire pump manifold. one pump must meet the requirements of both systems simultaneously.

A.5.2.2. Sprinkling System

(1) Regardless of where connected, combined capacity of all fire pumps must be capable of supplying the sprinkler system while meeting hose stream requirements. Great care must be taken when arranging more than one fire pump to discharge into a single fire

main. Unless the pump curves are identical, each pump will not discharge at its rated capacity. For example, two pumps rated individually at 250 gpm may only deliver 400 gpm when used in combination.

A.5.2.3. Water Spray

(1) The objective is rapid operation of the system; pump room fires may easily reach temperatures of 2000^0F within 3 minutes. A pump must be reserved exclusively for the spray system or one of the required pumps increased by the capacity of the spray system. However, this assumes that the water spray system is connected to the fire main at other than the fire pump manifold. On tankers, if the water spray system connection is at the fire pump manifold, and so arranged that operation of the water spray system does not interfere with simultaneous use of the firemain, this would be acceptable. Such an arrangement is similar to what is required for foam systems.

For further clarification of acceptable pumping arrangements see sketches at end of this part (Subpart D - Pumping Configurations). The difference between the water supply requirement for a water spray system versus a 5prinkler system lies in the nature of the hazard protected. It is essential for water spray systems to be actuated quickly. This is more fully discussed in the parts on WATER SPRAY and on SPRINKLER systems.

A.6. RELIEF VALVES

Relief valves are required on the discharge side of all fire pumps. Discharge of the relief valve should be to a safe location. The relief valve piping should be without shut-off valves, so that the purpose of the relief valve is not defeated. Relief valves should be set to operate at l25[6] psi or 25 psi in excess of the pressure necessary to meet the hose stream requirements, whichever is greater. The required relief valve setting is determined by the following factors:

(1) Design pressure of the piping

(2) Maximum pressure to which a hose should be subjected, and

(3) Maximum hose nozzle pressure that can be safely handled by personnel.

The 125 psi limitation apparently Stems from the accepted service pressure for cast iron and galvanized steel fittings, formerly common in firemain use. This accepted service pressure has more recently been increased to 150 psi.
In event that pump pressures higher than 100 psi are required to meet hose stream requirements, the relief valve should be set to operate 25 psi in excess of the required pump pressure. This is intended to allow for aging of pumps and pipe, decreasing the over-all efficiency of the system. It also permits the use of a single hose at higher pressures.

[6] If the shut-off head of the pump does not exceed 125 psi, no relief valve is required.

Besides protecting the fire main from excessive pressure, the relief valve setting prevents excessive reactions to personnel holding the nozzle. Systems can be designed for pitot pressures up to 100 psi at the nozzle without fear of excessive reaction. The required SO psi pitot pressure gives only marginal fire-fighting capability. higher pressures provide more effective hose streams, particularly when spray applicators are used. Reactions experienced by personnel holding straight Stream nozzles are directly proportional to the pressure (see Paragraph A.7.2 Nozzle Reaction).

The relief valve requirement should not preclude the installation of higher pressure fire-fighting appliances, providing such appliances are not hand held. For example, high pressure monitors are acceptable. When a fire pump is used for services requiring a higher discharge pressure than the fire main, the relief valve should be installed in the fire main near the fire pump manifold, and not at the discharge of the pump. A diagrammatic of such an arrangement is shown in Subpart D - PUMPING CONFIGURATION #1.

A.7. NOZZLES

A.7.l. Discharge

Smooth bore nozzles shall be of bronze or equivalent metal. These nozzles are not type-approved or listed in CG-l9O, Equipment Lists. Nozzle orifice sizes are required to be as sized per table 76.10-5(a) & 95.10-5(a). The characteristics of water discharge from smooth bore nozzles may be described by

$$Q = K\sqrt{P} \ ,$$

where: Q = flow (gpm)
K = constant
P = pressure (psig)
For 5/8" nozzle K = 11.70 (1 ½” hydrant)
For 7/8" nozzle K = 22.78 (2 ½” hydrant)

It will be noted that at 50 psi pitot pressure,

$$Q\left(\tfrac{5}{8}\right) = 11.70\sqrt{50} = 82.7 gpm$$
$$Q\left(\tfrac{7}{8}\right) = 22.78\sqrt{50} = 161.0 gpm$$

or the discharge from one-2 1/2" hydrant with 7/8" nozzle is approximately twice that from one-l 1/2" hydrant with S/S" nozzle.

A.7.2. Reaction

The reaction force experienced by personnel holding a smooth bore nozzle is due to the acceleration of water through the nozzle (Fm ma). It 'may be calculated by the equation:

F = 1.57D^2p[7]

[7] NFPA Fire Protection Handbook, Thirteenth Edition (p. l2-39)

where F = reaction force (pounds)
D = orifice diameter (inches)
p = pitot pressure (psig)

The reaction of spray nozzles or applicators is considerably less. Combination nozzles and applicators are required to be approved and listed in the Equipment Lists (CG-190). Where combination nozzles are required for protection against class B fires, clips should be provided on the bulkhead near the nozzle for holding the applicator. Be certain that the applicator is of a size and type to fit the nozzle provided.

A.8. HYDRANT SPACING

Hydrants must be so located that two effective hose streams may be directed into all portions of the vessel accessible to passengers and crew as the vessel is being navigated; one[8] of the streams shall be from a single length of hose. It is essential that the hose is long enough to direct water into all portions of the apace and not just long enough to let the nozzle to the door. Increased lengths are not permitted for compliance with this requirement[9]. All hose of the same diameter should be of game length. Once the hoses are removed from the hydrants for testing or cleaning, there is no assurance that the proper length hose will be restored to the required location.

The effective horizontal reach of 5/8" smooth bore nozzle in still air is just under 1 foot per psi nozzle pitot pressure, being about 47 feet at 50 psi. The effective, horizontal reach of a 7/8" smooth bore nozzle in still air is about 52 feet at 50 psi. If combination nozzles are installed for class 3 (flammable liquid) protection, the spacing should be based upon the assumption that the spray pattern is used (spray pattern range is about 20-25 feet in still air).

A.9. AUTOMATION

In addition to the foregoing information for all vessels, the following data for automated vessels is as follows:

(1) Controls for fire pumps located within the engineroom should be included at the engineroom control station. Sufficient controls should be provided to enable the watch to charge the fire main from the engineroom control station.

(2) Controls for fire pumps located outside the engineroom may be included at the engineroom control station. Damage to these controls should not prevent operation of the pumps from the pump location.

(3) On ships with unattended machinery spaces at least one of the fire pumps shall be controlled from the bridge as well as one controlled from the engineering control station. This control station shall include control of the associated pump suction and discharge valves. Instrumentation shall be provided at or adjacent to the fire

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[8] For portions of machinery spaces, two streams must be from single lengths of hose.
[9] On the weather deck of tank vessels, the length of the hose may be increased if necessary to allow a single length of hose to be goosenecked over the side of the vessel. If two fire mains are installed, the length of the hose shall be such that a single length of hose may be goosenecked 5rom the nearest fire main.

pump controls to indicate that adequate fire main pressure is available. Inadequate fire main pressure shall be alarmed at the control station and bridge.

B. DESIGN AND REVIEW OP SYSTEM

This subpart provide. a check-list type of outline for essential items which should be considered in designing and reviewing fire main systems. For interpretation of individual items reference should be made to the preceding subpart. In case of any doubt, the applicable regulations should be consulted for exact wording of requirements.

Application: Passenger and Cargo - All fire main installations contracted for on or after November 19, 1952.

Tank - All fire main installations contracted for on or after January 1, 1962.

Tire pumps, piping, hydrants, hose and nozzles are required to be installed on all self-propelled vessels[10]. In addition, they are required on all passenger barges with sleeping accommodations for more than six persons, and all cargo barges with sleeping accommodations for more than 12 persons.

Numbers in parentheses refer to applicable regulations.

B.1. Determine number of pumps required according to size of vessel (tables 34., 76., and 95.10-5(a)).

B.2. Determine location of pumps. On vessels with oil fired boilers, either main or auxiliary, or with internal combustion propelling machinery, pumps, sea suctions, and sources of power must be arranged so that one fire will not eliminate all pumps (34.10-5(f), 76.10-5(h) and 95.10-5(h)). CO_2 protection may be substituted for separation of pumps in very special cases on small vessels only.

B.3. Determine required sizing of pump. On passenger vessels, must (A) meet hose stream requirements (tables 76., and 95.10-5(a)) and (B) total capacity must equal 213 of required bilge pump capacity, for cargo and tank vessels capacity of single fire pump must equal 2/3 of required bilge pump (34., 76., and 95.10-5(b)). Pumps to be used for other fire systems (than fire main) must be sized accordingly. Fire pump characteristic (capacity vs. head) curve should be required.

B.4. Pump sizing must be sufficient to meet hose stream requirements (table 34., 76., and 95.10-5(a) and (c)). This is a performance requirement. Additional pipe sizing requirements are contained in the previous section.

B.5. Fire pumps may be used for other purposes providing at least one pump is available for use on the fire main at all times (76. and 95,10-5(f), 34.10-5(e)).

B.6. Connections to fire main for purposes other than fire-fighting or deck wash (and tank cleaning on tankers) must be from a manifold near the pump (76., and 95.10-5(f), 34.10-5(e)) unless it can be shown that the pump still meets the capacity requirement over and

[10] Excepting tank vessels less than 100 feet in length.

above extraneous Use. Valves must be near the pump and so arranged that the pump may be put on the fire main quickly in event of an emergency.

B.7. Fire pumps shall be fitted on the discharge side with a relief valve set to relieve at either 125 psi (Passenger & Cargo only) or 25 psi greater than necessary to meet the hose strewn requirements, whichever is greater (76., and 95.10-5(d), 34.10-5(c)). If the shut off head of the pump does not exceed 125 psi no relief valve is required (Passenger & Cargo only). This can be interpreted to mean protection for the fire main if the pump is used for other purposes. See further discussion in previous subpart.

B.8. Locate relief valve at discharge of fire pump. Should be through a line that is not valved lest the purpose of the relief valve be defeated.

B.9. Fire pumps are required to be fitted with a gauge on the discharge side of the pump.

B.l0. Determine hydrant spacing. Hydrants must be sufficient in number and so arranged that all portions of tile vessel accessible to passengers or crew, except machinery spaces, while the vessel is being navigated, may be reach with two hose streams, one of which is required to be from a single length of hose (76., and 95.10-10(d), 34.10-10 (b)). Size of hose and nozzles indicated in tables 34., 76., & 95. L0-5(a). On passenger vessels all watertight doors, doors in MVZ's, and stairway enclosures shall be assumed closed in checking compliance with this requirement. Spacing should be checked to scale on the plan, but due to obstructions, and arrangement of vessel, final determination should be left to the OCMI on the actual vessel. Where combination nozzles are installed for class B (flammable liquid) protection, discharge should be assumed to be from the <u>spray</u> pattern.

B.11. Fire stations should be numbered sequentially as required by regulation on all vessels to be certificated by the Coast Guard. See 37, 40-15, 78.47-20, and 97.37-15.

B.12. Provide shore connections. Cargo, Passenger, and Tank vessels over 1000 gross tons are required to be fitted with a shore connection on both sides of the vessel, with suitable adapters and cut-out valves.

B.13. The outlet at the fire hydrant shall be any position from the horizontal to vertical downwards to minimize the possibility of the hose kinking (76., and 95.10-10(f), 34.10-10(c)).

B.14. Suitable shut-off valves are required to be installed in the firemain on tankers to assure continued operation in event of damage (34.10-15 (b), and 34.20-5(e)).

B.15. All parts of the fire main located on exposed decks shall be protected against freezing or fitted with suitable cut-out valves and drains so that the piping may be drained in cold weather (76., & 95.10-10(e)).

8.16. Use of fire hose for purposes other than fire extinguishing and fire drills is prohibited (76.10-10(i), 34.10-10(j)).

8.17. Hose is required to bear tile Underwriters Laboratory label or comply with Federal Specification JJ-II-571 or ZZ-II-451a (34., 76., & 95.10-10(1)).

8.18. Provide acceptable nozzles. Smooth bore nozzles shall be of good grade bronze or equivalent metal (76.10-10(j), 95.10-10(i)). Smooth bore nozzles shall be of a size required by tables 76., and 95.10-5 (a), but proprietary approval by the Coast Guard is not required. Where combination nozzles are required, they are to be of an approved type listed in Equipment Lists, CG-190 (76.l0-10(j)(3), 95.10-10(i) (3), 34.10-10(e)). Applicator should be stowed on bulkhead near nozzle and be of a size and type to fit the nozzle.

8.19. Fire hose shall be carried connected to the hydrants at all times except where the hose may be damaged by heavy weather or when it interferes with handling of cargo (76., and 9S.10-l0(g), 34.10-10 (k)). Hoses shall be stowed in accordance with 76., and 95.10-10(h), 34.10-10(e)) which states that they must be adjacent to the hydrant and conspicuously marked.

C. TESTING AND INSPECTION

C.l. <u>INITIAL INSPECTION</u>

C.1.l. Test system to determine that pumping capacity is sufficient to adequately supply the required number of hose streams. For cargo and passenger vessels, this can be determined by using a single pump and simultaneously flowing the two highest.2 1/2 inch outlets. For tank vessels, this can be determined by using a single pump and simultaneously flowing the two-2 1/2" (three for tankers over (650') hydrants giving the greatest pressure drop between the hydrants and the pump. For cargo and passenger vessels the Pitot tube pressure should be not less than 50 psi, for tank vessels should be not less than 75 psi.

After checking capacity of the individual pumps, two pumps should then be operated simultaneously. Systems which are connected to the fire main, and which might be used at the sane time as the fire main, should be tested simultaneously. -

C.1.2. Review valve and piping arrangement near pump to make Certain that the fire pump may be put on the system quickly. All manifold valves should be near the pump.

C.l.3. Assure that pumps, sea suctions, power supply, and cable are segregated so that one casualty will not put both pumps out of operation.

C.l.4. Hydrant locations should be examined to determine that all portions of vessel accessible during voyage may be reached with two streams of water, one of which shall be from a single length of hose.

C.l.5. Examine hose to assure proper diameter, length, and marking.

C.l.6. Determine that hose is properly stowed, and connected to fire main. hose shall be visible or stowage clearly marked.

C.l.7. If combination nozzles are required, assure that they are of an approved type. Check stowage 6f applicator, should be on bulkhead near nozzle and be of a size and type to fit the nozzle.

C.l.8. Determine that fire stations are legibly marked and numbered as required.

C.l.9. Check shore connections and arrangement.

C.1.10. Assure that relief valve is set to operate properly, and discharges to an acceptable location.

C.1.11. Check to be certain that no connections, other than those specifically permitted, are made to the fire main.

C.2. PERIODIC INSPECTION

C.2.l. Assure that pumping capacity has not seriously deteriorated. This can be done by flowing the required number of hoses and checking Pitot pressure in accordance with C.1.1.

C.2.2. Check hose, stowage, marking, etc. of hose. Pressure test hose at 100 psi or the maximum pressure to which it will be subjected in service, whichever is greater.

C.2.3. Operate valves, pumps, etc. to assure firemain system is in good working order.

C.2.4. If vessel employs control starting of fire pumps check by operating pump from all remote control 8tations.

C.2.5. If vessel requires pressure alarm1 check by flowing enough hydrants to reduce pressure on fire Rain to point where alarm should sound.

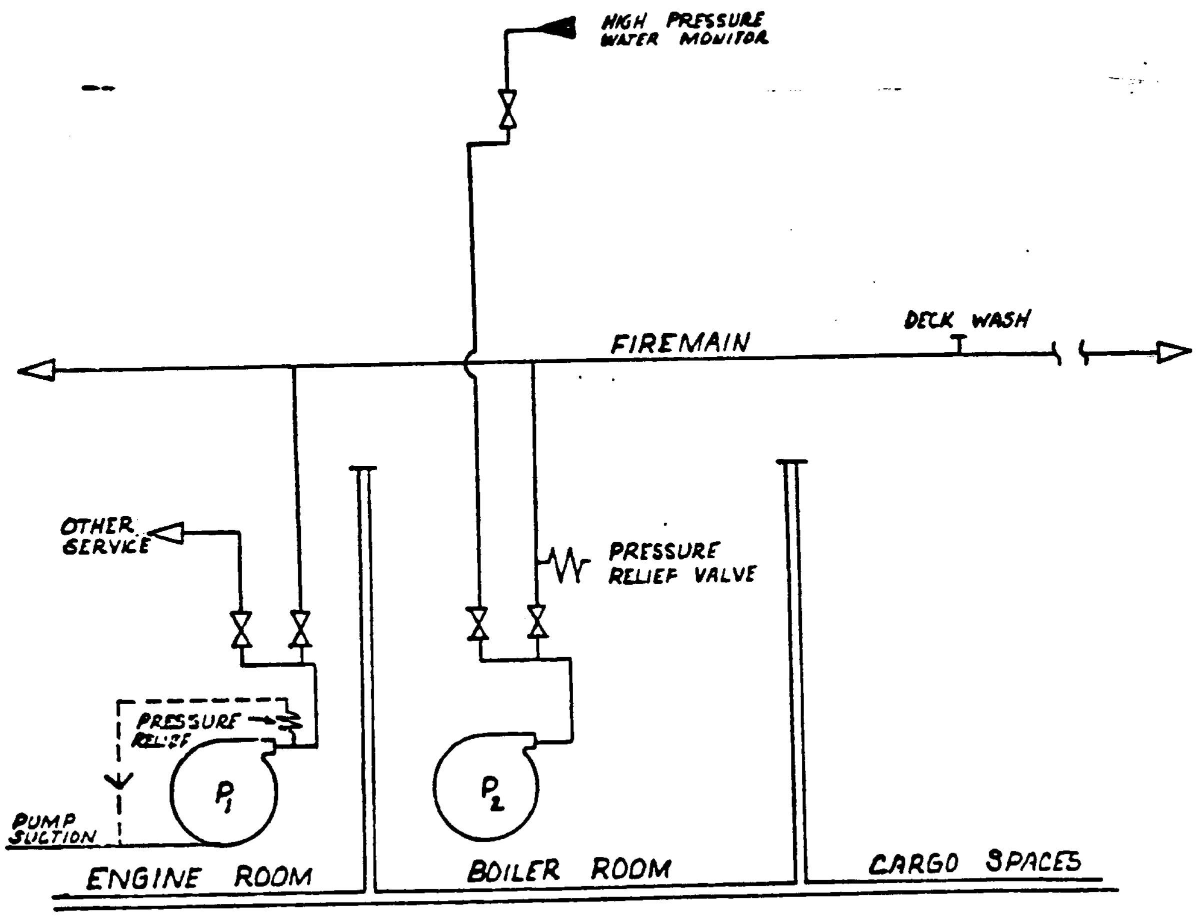
C.2.6. Check items (1.7), (1.10) and (1.11) above.

D. PUMPING CONPIGURATIONS

The following drawings are diagrams of acceptable fire pump piping arrangements. Schematics are intended to represent general piping runs only and should not be construed as showing the number of hose streams for which the system is required to be designed. Included are notes regarding required capacity of pumps with each configuration.

The drawings are intended for guidance only. Acceptable arrangements are not limited to those shown.

Figure I.D.1 - Acceptable Pumping Configuration No. 1



TYPICAL FIREMAIN SYSTEM AS MIGHT BE INSTALLED ABOARD PASSENGER OR CARGO VESSEL - WITH HIGH PRESSURE WATER MONITOR INSTALLED AS EXCESS EQUIPMENT.

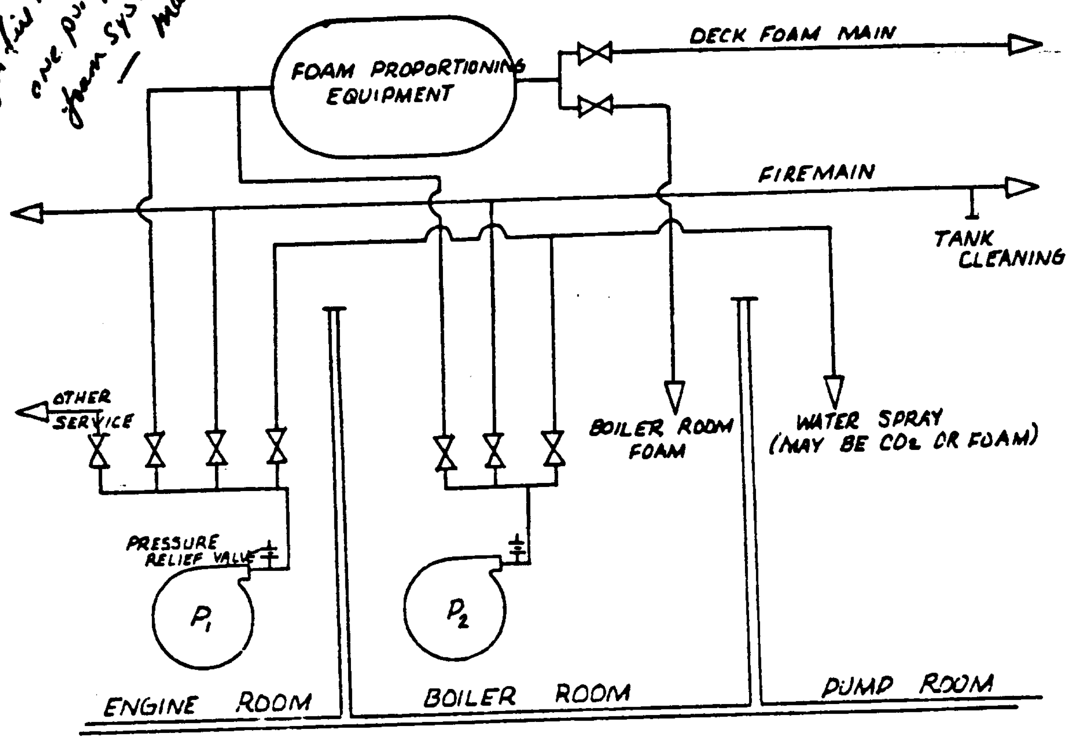
NOTES :

1. PRESSURE RELIEF FROM P_1 IS SHOWN DISCHARGING TO THE PUMP SUCTION. THIS IS A RECOMMENDED DISCHARGE ARRANGEMENT.

2. THE PRESSURE RELIEF VALVE FOR P_2 IS SHOWN ON THE SYSTEM SIDE OF THE FIRE MAIN SHUT OFF VALVE IN LIEU OF AT THE PUMP DISCHARGE. THIS IS TO PERMIT INSTALLATION OF THE HIGH-PRESSURE MONITOR. SEE SECTION A.6.

– one pump sized for fire main one pump sized for foam system – / manifold connections

Figure I.D.2 - Acceptable Pumping Configuration No. 2



TYPICAL FIREMAIN SYSTEM AS INSTALLED ABOARD TANK VESSEL WITH ALL CONTROLS VALVES LOCATED AT MANIFOLD NEAR PUMP.

DESIGN CONDITIONS:

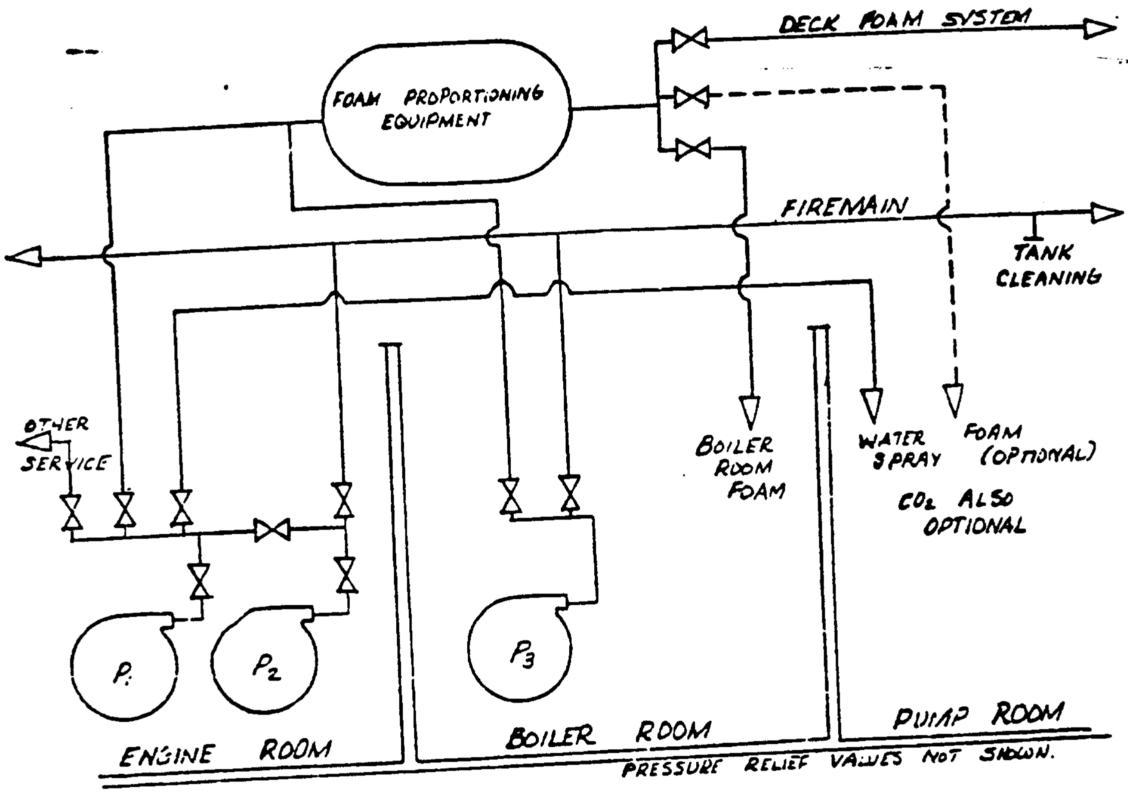
(1) Fire on Deck: P_1 on Foam Main, P_2 on Firemain (May be reversed)

(2) Fire in Pump Room: P_2 on Firemain, P_1 on Water Spray (May be reversed)

(3) Fire in Boiler Room: P_1 on Foam Main & Then Firemain - However, it is strongly recommended that P_1 be capable of supplying the foam system and firemain system simultaneously.
P_2 out of Service

(4) Fire in Eng. Room: P_1 out of Service
P_2 on Firemain

Figure I.D.3 - Acceptable Pumping Configuration No. 3



TYPICAL FIREMAIN SYSTEM AS INSTALLED ABOARD TANK VESSEL - ALL CONTROL VALVES NEAR PUMP & EXTRA PUMPING CAPACITY AVAILABLE.

DESIGN CONDITIONS:

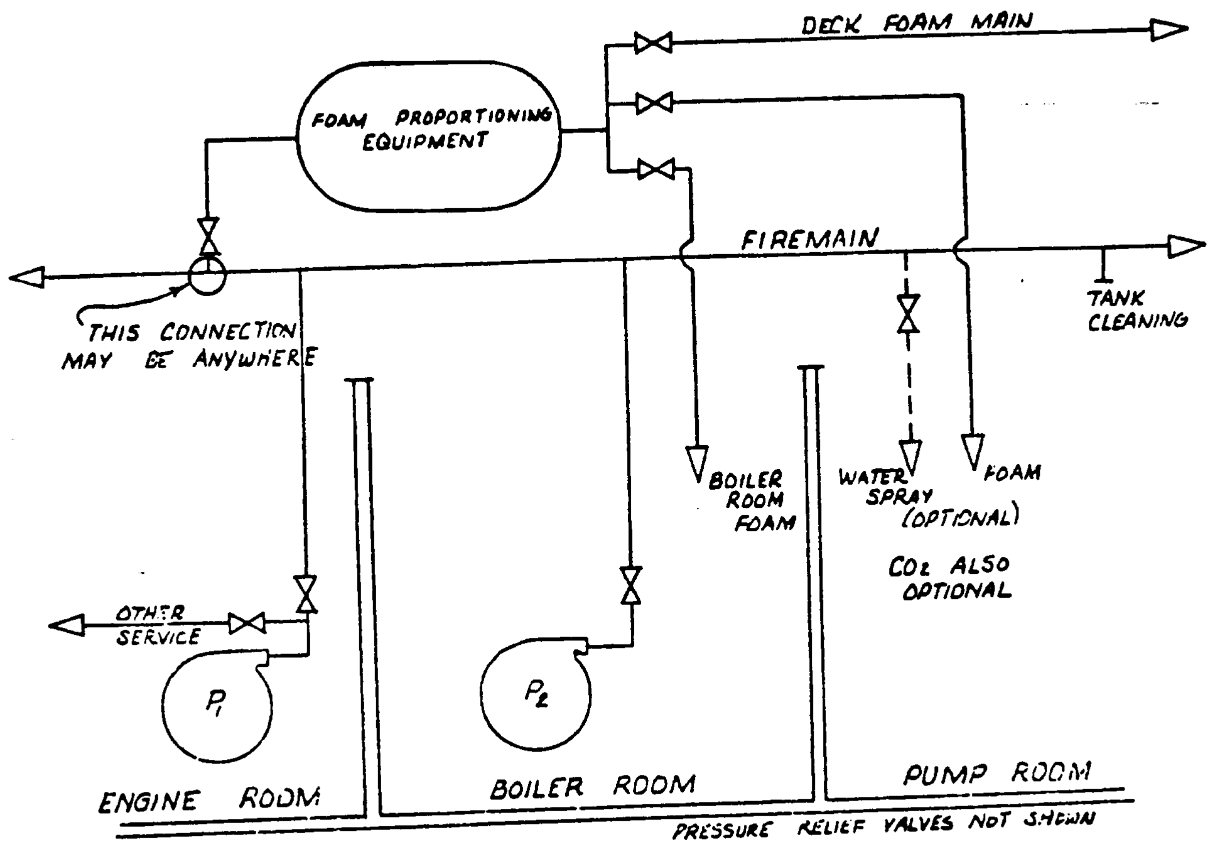
(1) Fire on Deck: P_3 on Deck Foam; P_2 (P_1 on Firemain) (May be other combination

(2) Fire in Pump Room: P_1 on Water Spray; P_3 (P_2) on Firemain

(3) Fire in Boiler Room: P_2 on Firemain; P_1 on Boiler Foam

(4) Fire in Eng. Room: P_3 on Firemain

Figure I.D.4 - Acceptable Pumping Configuration No. 4



TYPICAL FIREMAIN SYSTEM AS INSTALLED ABOARD TANK VESSEL
ALL VALVES NEAR EQUIPMENT

DESIGN CONDITIONS:

(1) Fire on Deck:	P_1 (P_2) on Firemain and Deck Foam
(2) Fire in Pump Room:	P_1 (P_2) on Firemain and Pump Room Foam (Water Spray)
(3) Fire in Boiler Room:	P_1 on Firemain and Boiler Room Foam P_2 out of Service
(4) Fire in Engine Room:	P_2 on Firemain

NOTE: P_1 & P_2 should have identical pump characteristics.

II. CARBON DIOXIDE

A. DISCUSSION

A.1 GENERAL

Carbon dioxide as an extinguishing agent has many desirable properties. It will not damage cargo or machinery and leaves no residue to be cleaned up after a fire. Even if the ship is without power a charged CO_2 system can be released. Since it is a gas, CO_2 will penetrate and spread to all parts of the space. It does not conduct electricity and therefore can be used on live electrical equipment. It can be effectively used on most combustible materials.

There are two disadvantages to carbon dioxide. It has little cooling effect on materials that have been heated by the fire, and the quantity available in a system is limited.

Carbon dioxide extinguishes fires by reducing the oxygen concentration to a point where the atmosphere will no longer support combustion. The CO_2 concentration must be maintained for a sufficient period to allow the maximum temperature to be reduced below the autoignition temperature of the burning material. Carbon dioxide is most effective against flammable liquid fires. In enclosed spaces, burning class A combustible (wood, paper, etc.) fires may not be completely extinguished but may be controlled. For most flammable liquids, reduction of the oxygen concentration to 15% (from the normal 21%) will be sufficient to extinguish the fire. For class A combustibles, a reduction to 15% will control the fire. Some materials, such as acetylene and ethylene oxide, require a greater reduction of oxygen concentration for extinguishment. Still other materials, such as cellulose nitrate and metal hydrides, which do not require environmental oxygen as they burn, cannot be extinguished by use of carbon dioxide.

A.2. TYPES OF MARINE SYSTIMS

There are two basically different systems for the protection of spaces with carbon dioxide, depending upon the hazardous material involved. These two systems may be classified as "cargo" systems and "total flooding" systems.

A.2.l. Cargo System

Fires in class A combustibles carried in cargo holds generally start with some smoldering and production of large quantities of smoke. Only when sufficient heat is developed to reach the "flash over" temperature (temperature at which solid combustibles give off sufficient gases to support continued rapid combustion) will rapid burning occur. Until this time the rate of burning is relatively slow. Time to flash-over for ship's holds would perhaps be at least 20 minutes depending upon oxygen available and other circumstances. This allows tine to prepare fire fighting operations and techniques. Carefully 5ealing the hold prior to release of CO_2 is extremely important. Cargo Systems are intended for use against this type of fire. The correct fire fighting technique with a cargo system is to secure all openings to the space and manually release an initial charge of CO_2 (this quantity will be contained in the instruction book carried aboard the vessel - the instruction book should be prepared in accordance with Coast Guard recommendations, and submitted for Coast Guard approval) until sufficient concentration is developed to bring the fire under control. The hatch covers are maintained in place and additional CO_2 released from time to time (according to the system instruction booklet) to maintain the concentration. This method also allows control of the amount of CO_2 released depending upon how much and what type of cargo is in hold. Extinguishment of a class A type fire with carbon dioxide is difficult due to the thermal insulating properties of the material. Therefore, the hold is kept closed until the vessel reaches a port or other convenient facility where the hold can be opened, cargo removed, and final extinguishment accomplished. Usually such an operation involves removing cargo from spaces not involved in the fire while retaining an inert blanket on the portion of the hold involved. The fire-space is then opened, with charged firemain nozzles and water spray applicators at the ready. The cargo, e.g. baled cotton, is unloaded, cooled with water or broken open if necessary to extinguish the fire.

A.2.2. Cargo Tank System

Cargo tanks aboard cargo and passenger vessels may be protected by a type of cargo system. No specific requirements are enumerated in the passenger and cargo regulations for these systems. Installation requirements should be based upon the subparagraph 34.l5-90(a)(3) of the Tank Vessel Regulations. This regulation calls for discharge of the required quantity of carbon dioxide within 5 minutes. The quantity of carbon dioxide required to protect a given space is based upon a volume factor of 30 (one pound of CO_2 per 30 cubic feet of space). Operating instructions should state the minimum number of carbon dioxide bottles to be released as related to the amount of cargo in the tank.

A.2.3. Total Flooding System

Fires in machinery and similar spaces are generally class B (flammable liquids). In this type of fire the heat build-up is rapid. -The safety of the ship depends to a great extent upon the contents of the machinery space. For this reason, it is important to introduce the extinguishing gas quickly. This also prevents heat from possibly causing failure of bulkheads, making it impossible to maintain CO_2 concentration. Quick release keeps structural members from reaching high temperatures. It also prevents heat updraft from the fire from carrying away the carbon dioxide, as well as limiting damage to equipment. discharge of 35% of the required quantity of CO_2 in these systems should be completed within two minutes; slow release might result in no extinguishment. The separate and deliberate operations are required to avoid unintentional release of the gas. one control shall release at least the required amount of CO_2. Another control is required to operate the stop valve or direction valve.

Systems protecting enclosed ventilation system for motors and generators of electric propelling machinery are of the total flooding type. In addition, the required concentration of CO_2 must be maintained until the machinery can be stopped; this may require release of additional gas at delayed intervals. Such systems are described as "delayed discharge, total flooding" systems.

A.2.4. Special Suitable Space System

Ordinary cargo vessel fire extinguishment systems are not designed for protection against flammable liquid type of fires. To protect against the possibility of releasing the required quantity of CO_2 within a relatively short period. This would result in an increase over ordinary cargo vessel extinguishment system requirements by requiring an increased amount of piping and carbon dioxide nozzles. The amount of CO_2 required is based upon the gross volume of the largest “tight” space divided by a volume factor of 22 (one pound of CO_2 per 22 cubic feet of space). The “tight space” allows for small openings in hatches. Therefore, in designing a system for a volume factor of 22 for the “tight space” in 2 minutes, there is sufficient CO_2 available for a volume factor of 30 for the whole hold. The discharge of the required CO_2 is to be completed within 2 minutes.

A.3. CARBON DIOXIDE CONCENTRATION

Reduction of oxygen content to 15% is sufficient to extinguish most fires. Developing a CO_2 concentration of 28.5% in the atmosphere will reduce the oxygen content to 15%. The volume of carbon dioxide required to develop a given concentration in the atmosphere, assuming free efflux[11], is expressed by

$$x = \frac{\log_{10}\left(\frac{100}{100 - \%CO_2}\right)}{.434}$$

(NFPA No. 12 - Carbon Dioxide Extinguishing Systems, page 12-64)

where x = volume of CO_2 added per volume of space. Although Coast Guard regulations were actually developed empirically, it is of interest to see how this relates to Coast Guard requirements. To apply this formula, assume that one pound of carbon dioxide expands to 9 cubic feet when released and apply a volume factor of 22 (from Coast Guard regulations for machinery spaces over 50,000 ft^3) to determine the pounds of CO_2 required. The concentration of C02 developed in such a space (per 100 ft^3) may be calculated as follows:

$$100\,ft^3 \times \frac{lbCO_2}{22\,ft^3} \times \frac{9\,ft^3}{lbCO_2} = 40.9\,ft^3 CO_2 \;/\; 100\,ft^3 space = x$$

$$\frac{40.9}{100} = \frac{\log_{10}\left(\frac{100}{100 - \%CO_2}\right)}{.434} \qquad \%CO_2 = 33.5\%$$

This concentration is sufficient to reduce the to approximately. 13.9%.

For cargo spaces, a volume factor of 30 (based upon gross volume of largest hold) is used to determine the quantity of CO_2 required. This is equivalent to

$$100\,ft^3 \times \frac{lbCO_2}{30\,ft^3} \times \frac{9\,ft^3}{lbCO_2} = 30\,ft^3 CO_2 \;/\; 100\,ft^3 space = x$$

$$30 = \frac{\log_{10}\left(\frac{100}{100 - \%CO_2}\right)}{.434} \qquad \%CO_2 = 25.9\%$$

[11] “Free efflux" means application of carbon dioxide in which the displaced atmosphere is exhausted freely through various small openings as carbon dioxide is injected. Some carbon dioxide is therefore lost with the vented atmosphere. The loss is greater at higher concentrations.

Because shipboard installations generally have fewer openings (portholes, etc.) than land installations, and they are at higher levels in the space, the carbon dioxide is not readily diluted but tends to remain near the bottom of the space where burning is likely to occur. This is a preferred condition.

Introduction of this percentage of carbon dioxide will reduce the oxygen Content of the space to 15.5%. It might appear at first glance that the oxygen content cannot be reduced enough, using a factor of 30, to extinguish the fire. However, i~ computing the volume of the space protected 110 reduction in volume is allowed for items of bulk which may be stowed in the space. As fires in cargo holds ordinarily occur with some stowage in the hold, the actual volume of atmosphere to be inerted is less than the gross volume of the hold. In addition, and most importantly, no consideration is given to the fact that once a hold is sealed up, the fire itself will consume a portion of the oxygen, thereby reducing the 02 concentration of the atmosphere prior to C02 release. Consequently, the oxygen content of the atmosphere actually in the hold would be reduced considerably below 15%. In the case of cargo tanks, it may be desirable to require sufficient C02 to reduce the oxygen content to l5'~. The above discussion is not applicable to machinery spaces as reduction in the volume of the protected space is allowed for boiler casings, etc. which extend into the space.

A.4. VOLUME FACTOR

As the volume of a space increases the proportional amount of CO_2 required to protect that space decreases (the volume factor in Coast Guard regulations increases). The smaller the volume of a space the greater the ratio of surface area to volume and consequently the greater the ratio of access openings to volume. Therefore, for smaller spaces there is a relatively greater chance of CO_2 leakage from the space. An additional factor is that of ventilation. While mechanical ventilation Systems are required to be shut down and ventilators closed upon actuation of a system, the presence of a ventilation system allows loss of some extinguishing gas.

A.5. NOZZLE SPACING

Coast Guard regulations state that nozzles should be spaced to give a “relatively uniform” discharge. In enclosed spaces, such as aboard ship, the location of nozzles is not so critical as for foam and water spray Systems. The carbon dioxide will disperse to all portions of the hazard within a relatively short period. Spacing the nozzles in some uniform pattern simply reduces the time necessary for the gas to mix with the air and completely inert the space. In a machinery space location of nozzles at a height equal to one-third to one-half the height of the space is adequate. since CO_2 is heavier than air it will tend to remain in the lower portions of the space and the air forced out the top will contain little CO_2.[12] Nozzles should not be located near ventilation or other openings as there is a relatively greater chance of CO_2 being forced out of the opening.

A.6. NOZZLE DESIGNATION

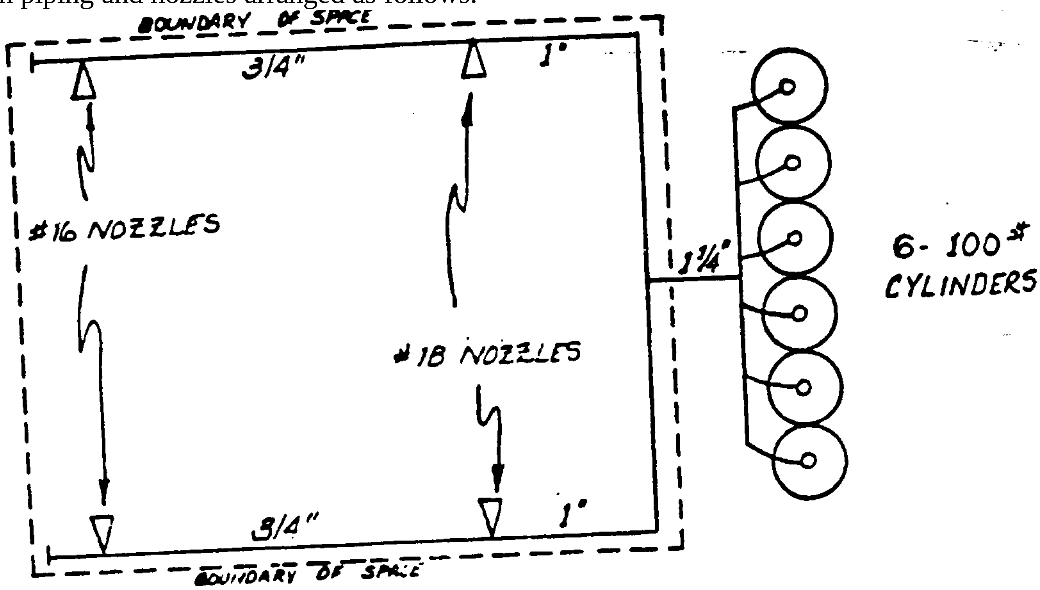
Discharge nozzles should be permanently marked to identify the nozzle and show the equivalent single orifice diameter. This equivalent diameter refers to the orifice diameter of the "standard" single orifice having the same flow rate as the nozzle in question. The equivalent orifice code number refers to the "standard" orifice diameter in 1/32" increments. For example a #16 nozzle has a discharge equivalent to a "standard" orifice 16/32" or 1/2" in diameter. A plus sign following the code number indicates equivalent diameters 1/64" greater than that indicated by the numbering system. For example, an 8+ nozzle has the equivalent discharge of a 17/64" standard orifice. See NFPA No. l2[4] for complete listing.

A.7. PIPE SIZING, NOZZLE SIZING, DISCHARGE TIME

[12] During fire conditions, updraft from fire will tend to carry CO_2 away, making prompt action and closure of openings essential.

If the pipe and nozzle sizes are in accordance with the regulations for machinery and similar spaces, the required quantity of carbon dioxide will be discharged in less than two minutes. A satisfactory method for estimating the flow in branch lines is to assume that the gas will flow through the nozzles in direct proportion to the nozzle areas.

For example, assume a 12,000 ft^3 (12000 ft^3 / 20 ft^3 / lb = 600 lb CO_2 rqd) machinery type space with piping and nozzles arranged as follows:



The nominal cy1inder area is: 600 x .0022 = 1.32 in^2.
The area of 1 1/4 of extra heavy main supp1y pipe is: 1.283 in^2.

Since the area of the main supply pipe is smaller, the nozzle orifice area should be based upon this area. The total equivalent orifice area is:

#16 = .1964 in^2 x 2 = .3928 in^2
#18 = 2485 in^2 x 2 = .4970 in^2
TOTAL .8898 in^2
.8898 in^2 / 1.283 in^2 = 69.9% of pipe area.

Since this is between 35% (40% for cargo) and 85% of the pipe area the nozzle orifice size is satisfactory.

The flow through individual nozzles may then be approximated to be proportional to the orifice area, or:

$$flow\#16 = 600lb \times \frac{.1964}{.8898} = 132.4lb$$
$$flow\#18 = 600lb \times \frac{.2485}{.8898} = 167.6lb$$